



(11)

EP 1 295 084 B1

(12)

## EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:  
**12.02.2014 Bulletin 2014/07**

(51) Int Cl.:  
**G01B 11/275** (2006.01)      **G01B 21/26** (2006.01)  
**B62D 17/00** (2006.01)      **G01M 17/06** (2006.01)

(21) Application number: **01948761.0**

(86) International application number:  
**PCT/US2001/020454**

(22) Date of filing: **28.06.2001**

(87) International publication number:  
**WO 2002/001153 (03.01.2002 Gazette 2002/01)**

## (54) METHOD AND APPARATUS FOR MEASURING VEHICLE WHEEL SCRUB RADIUS

VERFAHREN UND VORRICHTUNG ZUR MESSUNG DES LENKROLLRADII EINES FAHRZEUGRADES

PROCEDE ET DISPOSITIF POUR MESURER LE DEPORT AU SOL D'UNE ROUE DE VEHICULE

(84) Designated Contracting States:  
**DE FR IT**

(74) Representative: **Eisenführ Speiser Patentanwälte Rechtsanwälte PartGmbB Postfach 31 02 60 80102 München (DE)**

(30) Priority: **28.06.2000 US 214390 P**

(56) References cited:  
**EP-A- 0 971 205 DE-A- 2 650 577**  
**DE-C- 19 634 505 US-A- 4 479 382**  
**US-A- 5 090 235 US-A- 5 291 660**  
**US-A- 5 969 246**

(43) Date of publication of application:  
**26.03.2003 Bulletin 2003/13**

- **GODDARD S; ELWOOD P: 'SCRUB RADIUS AND SUV HANDLING' AUTOMOTIVE ENGINEERING INTERNATIONAL vol. 107, no. 7, 01 July 1999, WARRENDALE, PA, US, pages 32 - 41**
- **'SCRUB RADIUS AND SUV HANDLING' AUTOMOTIVE ENGINEERING INTERNATIONAL vol. 107, no. 7, 01 July 1999, WARRENDALE, PA, US, pages 32 - 41, XP000930745**

(73) Proprietor: **Snap-on Incorporated Pleasant Prairie, Wisconsin 53158-1603 (US)**

(72) Inventors:

- **JACKSON, David, A.  
Point Roberts, WA 98281 (US)**
- **GLICKMAN, Stephen, L.  
Los Gatos, CA 95032 (US)**
- **DALE, James, L., Jr.  
Conway, AR 72032 (US)**
- **HEALY, Donald, A.  
Conway, AR 72032 (US)**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

## Description

**[0001]** The present disclosure generally relates to motor vehicle maintenance equipment and methods and, more specifically, to apparatus and methods for measuring a scrub radius of a motor vehicle.

**[0002]** Motor vehicle alignment systems are important for ensuring that the alignments of wheels on a vehicle are within the specifications provided by motor vehicle manufacturers. If the wheels are out of alignment, there may be excessive or uneven wear. In addition, the performance of the vehicle, particularly handling and stability, may be adversely affected if the wheels are not properly aligned. As used herein, the term "wheel" or "vehicle wheel" refers to the tire and wheel assembly found on a motor vehicle. Such an assembly generally includes a conventional tire that is mounted on a metal wheel or "rim."

**[0003]** The wheels of a motor vehicle may be aligned in a number of ways. For example, an operator or an alignment technician can use a vision imaging system such as a computer-aided, three-dimensional (3D) machine vision alignment system having optical sensing devices, such as cameras, to determine the positions of various objects. Although such machine vision systems are typically used for alignment purposes, these systems can also be used to obtain other positional and angular orientation information about a motor vehicle. Examples of alignment systems using at least one camera to image targets attached to the wheels of a vehicle are shown in U.S. Patent Nos. 5,724,743 and 5,535,522.

**[0004]** Prior art document US 5 291 660 discloses a method of and an apparatus for determining caster and steering axis inclination angle of a steerable wheel of a vehicle, wherein specifically the caster angle or SAI angle or both of the steerable wheel are detected. To this end, the steerable wheels to be examined are steered to a given steering angle in both the rightward and leftward direction, and the displacement of a point on the wheel along the fore-and-aft axis or the transverse axis, or both, in the horizontal plane is measured. It is possible to calculate with a high degree of accuracy the caster angle and the SAI angle. Specifically, a linear displacement is measured of a point on the wheel in a plane parallel to the axes when the steerable wheel is turned to both predetermined positions. Moreover, the linear displacement of the support member of the wheel can be determined.

**[0005]** Moreover, prior art document US 5 969 246 discloses an apparatus for and a method of determining axial stability, wherein wheel runout and axial instability parameters are compared with prescribed tolerances to determine if the wheel suffers from an excessive wheel play. The vehicle wheel to be examined is rolled back a number of degrees from a first position to a second position and the attitude and location thereof are measured to determine a second vector in addition to a first vector being determined when the wheel of the vehicle to be examined is located at the first position. The wheel is

also rolled forward to a third position which is substantially equal to the first position, and measurements are taken resulting in a third vector. Forward and rearward axis parameters are determined and axial stability is determined based on the results obtained.

**[0006]** Another type of alignment system uses head units which are attached to various wheels and interconnected by cables or cords. The angles of the head units, and thus the wheels, with respect to the cords are measured by an electromechanical transducer. Examples of this type of measurement device are shown in U.S. Pat. Nos. 4,106,208 and 4,034,479.

**[0007]** An additional type of alignment system uses head units which attach to various wheels and communicate with optical sensing. Examples of optical head unit systems are shown in U.S. Pat. Nos. 3,782,831, 3,892,042, 4,095,902, 4,126,943, 4,138,825, 4,143,970, 4,302,104 and 4,319,838.

**[0008]** The above-described position determination systems provide information, such as the centers of rotation of the vehicle's wheels, which aids in the wheel alignment of a vehicle. However, other information such as wheel scrub radius, can also aid a technician in diagnosing problems with the vehicle's suspension. A scrub radius is the distance between where the wheel's steering axis meets the ground and where the wheel's centerline meets the ground, as viewed from the front of the vehicle.

**[0009]** Being able to measure and confirm the scrub radius of a wheel is important since the scrub radius in combination with rolling friction, such as brake drag, bearing friction and tire rolling friction, can create a moment about the wheel's steering axis during straight ahead driving, causing the wheel to toe-out or toe-in (pivot on the steering axis). Vehicle manufacturers often specify an opposite toe-out or toe-in to compensate for the known vehicle parameters, including scrub radius. Since the scrub radius should remain fixed if the rims and tire of a vehicle are stock, a measured scrub radius that does not match up with a manufacturer's specified scrub radius can be an indication of damage to the vehicle suspension and steering system. In addition, if aftermarket tires of a different diameter, or rims of a different offset are added to the vehicle, the scrub radius will be altered. The toe of the wheels may be compensated for the different scrub radius to minimize tire wear.

**[0010]** Based on the foregoing, there is a clear need in this field for an apparatus and method for measuring the scrub radius of the wheels of a motor vehicle.

**[0011]** There is also a need for an apparatus and method that compares the measured scrub radius of the wheels of a vehicle and the specified scrub radius of the wheels.

**[0012]** There is an additional need for an apparatus and method that displays the results of wheel scrub radius measurements to aid an alignment technician with detecting damaged vehicle suspension or steering parts, and with detecting whether the wheels are of the correct

specifications.

**[0013]** There is a further need for an apparatus and method that displays the results of wheel scrub radius measurements to aid an alignment technician with adjusting the toe of the wheel.

**[0014]** The foregoing needs are solved by a method according to claim 1 and by an apparatus according to claim 5. Further developments of the invention are set forth in dependent claims 2 to 4, and 6 to 10.

**[0015]** Additional aspects and advantages of the present disclosure will become readily apparent to those skilled in this art from the following detailed description, wherein only an exemplary embodiment of the present disclosure is shown and described, simply by way of illustration of the best mode contemplated for carrying out the present disclosure. As will be realized, the present disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** Reference is made to the attached drawings, wherein elements having the same reference character designations represent like elements throughout, and wherein:

FIG. 1 is a front elevation view of a front wheel of a vehicle (e.g., an automobile having four wheels) showing alignment properties of the wheel, including a steering axis, a rotation axis, a roll radius and a scrub radius;

FIG. 2 is a flow chart illustrating a method according to the present disclosure for determining the scrub radius of a vehicle wheel;

FIG. 3 is a flow chart illustrating a method according to the present disclosure for calculating a new toe for a vehicle wheel based upon the measured scrub radius of the wheel;

FIG. 4 is a perspective view of a computer-aided, three-dimensional (3D) machine vision alignment apparatus, which can be used for carrying out the methods of FIGS. 2 and 3; and

FIG. 5 is a block diagram of a computer system for use with the apparatus of FIG. 4.

#### DETAILED DESCRIPTION OF THE DISCLOSURE

**[0017]** Referring to FIGS. 1 and 2, the present disclosure provides a method 100 for determining a scrub radius 10 of a vehicle wheel 22. However, before the meth-

od of FIG. 2 is discussed, a description of the scrub radius 10 and other alignment measurements of a wheel 22 is provided.

#### 5 Scrub Radius

**[0018]** As shown in FIG. 1, scrub radius 10 is the distance between where a steering axis 14 of the wheel 22 intersects a ground plane 16 of the wheel, and where a centerline 18 of the wheel intersects the ground plane 16, as viewed from the front of the vehicle. The scrub radius 10 shown in FIG. 1 is positive, but if the steering axis 14 intersects the ground plane 16 outside of the centerline 18, then the wheel will have a negative scrub radius.

**[0019]** The steering axis 14 passes through steering pivots 15 of the wheel 22, while the centerline 18 of the wheel can be determined as the midpoint of a width of the tire. A roll radius 17 of the wheel 22 is the distance between the ground plane and a central or roll axis 19 of the wheel.

**[0020]** Being able to measure and confirm the scrub radius 10 of the wheel 22 is important since the scrub radius can create a drag on the wheel during straight ahead driving, causing the wheel to toe-out or toe-in and pivot on the steering axis 14. As is known, if wheels on the same axle point straight ahead they have zero toe, while wheels that point towards each other have toe-in, and wheels that point away from each other have toe-out. Vehicle manufacturers often specify a slight amount of toe-in to compensate for a positive scrub radius 10, and a slight amount of toe-out to compensate for a negative scrub radius. Since the scrub radius 10 should remain fixed if the rims and tire of a vehicle are stock, a measured scrub radius that does not match up with a manufacturer's specified scrub radius can be an indication of damage to the vehicle suspension and steering system. In addition, if after market tires and rims or a different size tire or rim are added to the vehicle, the measured scrub radius can be used to adjust the toe of the wheels and compensate for the different tires. Thus, the present disclosure provides the method 100 of measuring the scrub radius 10 of the vehicle wheel 22.

#### 45 Method of Measuring a Scrub Radius of a Vehicle Wheel

**[0021]** Referring also to FIG. 2, the method 100 includes first determining the steering axis 14 of the wheel 22, as shown at 102, and determining the centerline 18 of the wheel, as shown at 104. Then, the location of the ground plane 16 is determined, as shown at 110, based upon the rotation or roll axis 19 and the roll radius 17 of the wheel 22, which are determined, respectively, as shown at 106 and 108. At 112 and 114, the intersection of the steering axis 14 and the ground plane 16 and the intersection of the centerline 18 and the ground plane 16 are determined. The scrub radius 10 is then determined by measuring the distance between the intersections, as

shown at 116.

**[0022]** Referring to FIG. 3, a method 200 of using the measured scrub radius 10 is shown. The method 200 first includes comparing the measured scrub radius 10 to a specified scrub radius 10 for the particular vehicle, such as provided by the vehicle manufacturer. If the measured scrub radius 10 is not about equal (or within a predetermined tolerance of being equal) to the specified scrub radius 10, as shown at 204, then a notification is provided, as shown at 206, to an alignment technician for example. Then, if the alignment technician decides to adjust a toe of the wheel 22 to compensate for the incorrect scrub radius 10, as shown at 208, a new toe can be calculated, as shown at 210, and then indicated to the technician, as shown at 212. The correct toe adjustment is dependent in most cases on the particular type of vehicle and on specifications provided by the vehicle manufacturer.

**[0023]** The methods 100,200 of FIGS. 2 and 3 are conducted using a computer-aided, three-dimensional motor vehicle wheel alignment apparatus 300 ("alignment apparatus"), such as the type shown in FIG. 4. The Visuliner 3D Gold™ Aligner, for example, is an alignment apparatus that can be used to determine the scrub radius of a vehicle in accordance with the present invention, and is available from the John Bean Company of Conway, Arkansas ([www.johnbean.com](http://www.johnbean.com)). Although, FIG. 4 shows a two-camera alignment apparatus 300, the presently disclosed methods 100, 200 are not meant to be limited to a particular wheel alignment apparatus, and can be carried out using other types of computer-aided alignment systems, such as a single-camera alignment apparatus or alignment systems using head units which attach to various wheels and communicate with cables or optical sensors.

#### Alignment Apparatus

**[0024]** FIG. 4 is a block diagram illustrating the alignment apparatus 300 for measuring and characterizing the scrub radius of front wheels 22L and 22R of a vehicle 20 in accordance with the present invention. As depicted, the vehicle 20, which also includes rear wheels 24L and 24R, is mounted on a vehicle supporting means that might include for example a lift rack 26. A target assembly 54 having a defined pattern or shape is affixed to each wheel of the vehicle 20.

**[0025]** The alignment apparatus 300 includes two optical sensing means 30 each having an interface to an electronic processing means 60. In the depicted embodiment, each of the optical sensing means 30 is a camera, and the processing means 60 is a computer system. The computer 60 preferably includes a visual display unit 72 and an operator interface or input means 74 such as a keyboard or remote input device. Computer-generated quasi-three-dimensional (3D) representation of the wheels being aligned may be depicted on the display unit 72 along with indicia of the detected alignment. In addition,

the display unit 72 may depict hints or suggestions to guide the alignment technician who is performing the wheel alignment. The computer 60 also includes data storage means for storing predetermined automotive dynamic stability tolerance data.

**[0026]** Each of the optical sensors 30 can view at least one of the target assemblies 54 mounted on the wheels, and form an image thereof as viewed from the perspective of the sensing means. Electronic signals corresponding to the images are transferred to processing means 60 which correlates the detected perspective image of each target with the known true shape and orientation of reference data. In so doing, the computer 60 relates the perceived dimensions of certain known geometric elements on each target with the orientation and dimensions of corresponding reference data. In this manner, the alignment apparatus 300 can determine the position and attitude of each wheel 22L, 22R, 24L and 24R of the vehicle 20.

**[0027]** In a typical operation, the alignment apparatus 300 works generally as follows: vehicle 20 is positioned on alignment rack 26, which is raised to allow the alignment technician to perform the alignment; targets 54 are mounted onto each of wheels 22L, 22R, 24L, and 24R; the alignment apparatus 300 forms a detected image of each target 54; and the detected images are processed in computer 60, which calculates the orientation of each of the targets. The computer 60 may also store values corresponding to the position of each detected image.

**[0028]** Typically, the spindle position is also located. In this operation, the computer 60 acquires images of the targets 54. The vehicle 20 is rolled back, and the computer 60 acquires a second set of images of the targets 54. The computer 60 computes the angle through which the vehicle was rolled back, and based on such calculation, determines the spindle location. Optionally, the vehicle 20 can be rolled forward and measured again as a check. The computer 60 may then calculate the actual orientation of the primary planes of each of wheels 22L, 22R, 24L, and 24R. A primary plane or claw plane is an imaginary plane at an outer face of the wheel with a generally vertical orientation that is parallel to the tread of the tire that is part of the wheel.

**[0029]** The results of the computations described above are displayed on the display unit 72. The computer 60 may also have the display unit 72 show instructions to the alignment technician as to what corrections may need to be made to correct any detected misalignment of wheels 22L, 22R, 24L, and 24R of the vehicle 20.

**[0030]** The computer 60 also calculates the roll radius 17 and the roll axis 19 of each wheel 22L, 22R according to known methods, such as those disclosed in International Publication No. WO 01/23834. The roll radius 17 value is then used to determine the location of the ground plane 16 (minus corrections for tire flex). The steering axis 14 is determined using the aligner. The alignment apparatus 300 may perform other required measurements, and further perform calculations and/or comparisons.

isons of the results and display the results of such measurements, calculations, and comparisons.

**[0031]** Once the scrub radius 10 is determined, the alignment apparatus 300 presents resulting values on the display unit 72 for evaluation. The alignment technician can then use such results to help diagnose the condition of the vehicle, the vehicle suspension, and the wheels. In addition, the alignment apparatus 300 is preferably programmed to compare the resulting values for each wheel. For example, the alignment apparatus 300 can compare the measured scrub radius 10 and the manufacturer's specified scrub radius. Further, individual scrub radius 10 measurements may be compared to a predetermined value, a predetermined range of values, or manufacturing specifications, and the alignment apparatus 300 can highlight any that fall outside those specified tolerances, such as by generating a warning message to alert the alignment technician. A warning to investigate wheel pull problems might be provided if the scrub radii of the front wheels do not match. A wide variety of potential comparisons of the scrub radius 10 measurements may be made in addition to those listed herein.

**[0032]** As a result of observing the results on the display unit 72, the alignment technician is better able to determine if there is a problem significant enough to cause excessive or uneven wear of the tires or degraded performance of the vehicle, such as decreased handling or stability. Furthermore, the alignment apparatus 300 is preferably programmed to determine a new toe for the wheel 22 based upon the difference between the measured scrub radius 10 and the specified scrub radius, and indicate the new toe value to the technician so that the toe can be adjusted.

#### Computer Hardware

**[0033]** FIG. 5 is a block diagram illustrating in greater detail the computer 60 for use with the alignment apparatus 300 of FIG. 4. The computer 60 includes a bus 62 or other communication mechanism for communicating information, a processor 64 coupled to the bus 62 for processing information, and a main memory 66, such as a random access memory (RAM) or other dynamic storage device, coupled to the bus 62 for storing information and instructions to be executed by the processor 64. The main memory 66 also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor 64. The computer 60 also includes a read only memory (ROM) 68 or other static storage device coupled to the bus 62 for storing static information and instructions for the processor 64, and a storage device 70, such as a magnetic disk or optical disk, is provided and coupled to the bus 62 for storing information and instructions. As shown, in addition to the display 72 and the keyboard 74, the computer 60 may also include a cursor control 76, such as a mouse.

**[0034]** The computer 60 is used for determining the scrub radius 10 of each of the front wheels of a motor vehicle, by carrying out the methods 100 and 200 of the present disclosure. According to one aspect, the scrub radius 10 is provided by the computer 60 in response to

5 the processor 64 executing one or more sequences of one or more instructions contained in the main memory 66. Such instructions may be read into the main memory 66 from another computer-readable medium, such as the storage device 70. Execution of the sequences of instructions contained in the main memory 66 causes the processor 64 to perform the methods provided by the present disclosure. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with 10 software instructions to implement the present disclosure. Thus, the present disclosure is not limited to any specific combination of hardware circuitry and software.

**[0035]** The term "computer-readable medium" as used herein refers to any medium that participates in providing 15 instructions to the processor 64 for execution. Such a medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media includes, for example, optical or magnetic disks, such as storage device 70. Volatile media includes dynamic memory, such as the main memory 66. Transmission media includes coaxial cables, copper wire and fiber optics, including the wires that comprise 20 bus 62. Transmission media can also take the form of acoustic or light waves, such as those generated during radio-wave and infra-red data communications.

**[0036]** Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, punchcards, paper-tape, any other physical medium with patterns of holes, 25 a RAM, a PROM, and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave as described hereinafter, or any other medium from which a computer can read.

**[0037]** Various forms of computer readable media may 30 be involved in carrying one or more sequences of one or more instructions to the processor 64 for execution. For example, the instructions may initially be carried on a magnetic disk of a remote computer. The remote computer can load the instructions into its dynamic memory and send the instructions over a telephone line using a modem. A modem local to computer 60 can receive the data on the telephone line and use an infra-red transmitter to convert the data to an infra-red signal. An infra-red 35 detector can receive the data carried in the infra-red signal and appropriate circuitry can place the data on bus 62. Bus 62 carries the data to main memory 66, from which processor 64 retrieves and executes the instructions. The instructions received by main memory 66 may 40 optionally be stored on storage device 70 either before or after execution by processor 64.

**[0038]** The computer 60 also includes a communication interface 78 coupled to bus 62. The communication

interface 78 provides a two-way data communication coupling to a network link 80 that is connected to a local network 82. For example, the communication interface 78 may be an integrated services digital network (ISDN) card or a modem to provide a data communication connection to a corresponding type of telephone line. As another example, the communication interface 78 may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, communication interface 78 sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.

**[0039]** The network link 80 typically provides data communication through one or more networks to other data devices. For example, the network link 80 may provide a connection through local network 82 to a host computer 84 or to data equipment operated by an Internet Service Provider (ISP) 86. The ISP 86 in turn provides data communication services through the world wide packet data communication network now commonly referred to as the "Internet" 88. Local network 82 and Internet 88 both use electrical, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on network link 80 and through communication interface 78, which carry the digital data to and from computer 60, are exemplary forms of carrier waves transporting the information.

**[0040]** The computer 60 can send messages and receive data, including program code, through the network (s), network link 80 and communication interface 78. In the Internet example, a server 90 might transmit a requested code for an application program through Internet 88, ISP 86, local network 82 and communication interface 78. In accordance with the present disclosure, one such downloaded application provides for determining the scrub radius 10 of the wheels of a motor vehicle as previously described.

**[0041]** The received code may be executed by the processor 64 as it is received, and/or stored in the storage device 70, or other non-volatile storage for later execution. In this manner, the computer 60 may obtain application code in the form of a carrier wave.

**[0042]** Thus, the present disclosure provides a method 100 and an apparatus 300 for determining a scrub radius 10 of a vehicle wheel 22. The specific methods and apparatus described in this specification have been presented by way of illustration rather than limitation.

## Claims

1. A method of measuring a scrub radius of a wheel, comprising the steps of:

determining a steering axis, a centerline and a ground plane of a wheel using a computer-aided

alignment apparatus,  
wherein the ground plane is determined on the basis of a determined roll axis and a roll radius of the wheel by rolling the wheel between a first and a second position,

determining an intersection between the steering axis and the ground plane of the wheel, determining an intersection between the centerline and the ground plane of the wheel, and determining a distance between the intersections, the distance comprising the scrub-radius of the wheel,

wherein the computer-aided alignment apparatus comprises a computer-aided, three-dimensional machine vision apparatus including optical scanning devices and optically scannable targets,

and the method also includes:

attaching an optically scannable target having a defined pattern to the wheel;

optically scanning the target when the wheel is in the first position, and creating and storing values representing the first position; and

optically scanning the target when the wheel is in the second position, and creating and storing values representing the second position;

determining the angle through which the wheel was rolled between the first and second position;

steering the wheel between the first and the second positions, and determining the steering axis of the wheel based on the stored position values; and

further comprising determining a thickness and a claw plane of the wheel and determining the centerline based on the thickness and the claw plane.

2. A method according to claim 1, wherein the intersection between the steering axis and the ground plane, the intersection between the centerline and the ground plane, and the distance between the intersections are determined using a computer-aided alignment apparatus.

3. A method according to claim 1, further comprising:

comparing the determined scrub radius to a specified scrub radius; and

generating a warning if the determined scrub radius is not about equal to the specified scrub radius.

4. A method according to claim 1, further comprising:

- comparing the determined scrub radius to a specified scrub radius; and calculating a new toe for the wheel if the determined scrub radius is not about equal to the specified scrub radius. 5
5. A computer-aided alignment apparatus for measuring a scrub radius of a wheel, wherein the computer aided apparatus includes: 10
- a target having a defined pattern and being fixedly attachable to the wheel;  
a vision imager for detecting a first image of the target when the wheel is in a first position and for detecting a second image of the target when the wheel is in a second position; and  
a data processor programmed to determine a scrub radius of the wheel according to the method of any of claims 1 to 4. 15
6. An apparatus according to claim 5, wherein the vision imager detects the first image of the target by optically scanning the target when the wheel is in the first position, and detects the second image of the target by optically scanning the target when the wheel is in the second position. 20
7. An apparatus according to claim 5, wherein the data processor is programmed to create and store values representing the first position of the wheel based upon the first image of the target, and create and store values representing the second position of the wheel based upon the second image of the target. 25
8. An apparatus according to claim 5, wherein the data processor is programmed to compare the determined scrub radius to a specified scrub radius, and generate a warning if the determined scrub radius is not about equal to the specified scrub radius. 30
9. An apparatus according to claim 5, wherein the data processor is programmed to compare the determined scrub radius to a specified scrub radius, and calculate a new toe for the wheel if the determined scrub radius is not about equal to the specified scrub radius. 35
- 40
10. A computer-readable medium carrying one or more sequences of instructions which, when executed by a processor, cause the processor to carry out the method according to one of the claims 1 to 4. 45
- 50
- Bestimmen einer Lenkachse, einer Mittellinie und einer Grundebene eines Rades unter Verwendung einer computergestützten Ausrichtungsvorrichtung, wobei die Grundebene auf Basis einer ermittelten Rollachse und eines Rollradius des Rads bestimmt wird durch Rollen des Rades zwischen einer ersten und einer zweiten Position, Bestimmen eines Schnittpunkts zwischen der Lenkachse und der Grundebene des Rades, Bestimmen eines Schnittpunkts zwischen der Mittellinie und der Grundebene des Rades, und Bestimmen eines Abstandes zwischen den Schnittpunkten, wobei der Abstand den Lenkrollradius des Rades enthält, wobei die computergestützte Ausrichtungsvorrichtung eine computergestützte dreidimensionale Maschinensichtvorrichtung enthält mit optischen Abtastvorrichtungen und optisch abtastbaren Zielen, und wobei das Verfahren ferner enthält:
- Anbringen eines optisch abtastbaren Ziels, das ein definiertes Muster aufweist, an dem Rad;  
optisches Abtasten des Ziels, wenn sich das Rad in der ersten Position befindet, und Erzeugen und Speichern von Werten, die die erste Position darstellen; und optisches Abtasten des Ziels, wenn sich das Rad in der zweiten Position befindet, und Erzeugen und Speichern von Werten, die die zweite Position darstellen;  
Bestimmen des Winkels, um den das Rad zwischen der ersten und der zweiten Position gerollt wurde;  
Lenken des Rades zwischen der ersten und der zweiten Position und Bestimmen der Lenkachse des Rades basierend auf den gespeicherten Positions値en; und ferner enthaltend das Bestimmen einer Dicke und einer Klaueebene des Rades und Bestimmen der Mittellinie basierend auf der Dicke und der Klaueebene.
2. Verfahren nach Anspruch 1, wobei der Schnittpunkt zwischen der Lenkachse und der Grundebene, der Schnittpunkt zwischen der Mittellinie und der Grundebene, und der Abstand zwischen den Schnittpunkten unter Verwendung einer computergestützten Ausrichtungsvorrichtung bestimmt werden. 55
3. Verfahren nach Anspruch 1, ferner enthaltend:
- Vergleichen des bestimmten Lenkrollradius mit einem spezifizierten Lenkrollradius, und Erzeugen einer Warnung, wenn der ermittelte Lenkrollradius nicht ungefähr mit dem spezifi-

### Patentansprüche

1. Verfahren zum Messen eines Lenkrollradius eines Rades, die Schritte enthaltend:

zierten Lenkrollradius übereinstimmt.

**4. Verfahren nach Anspruch 1, ferner enthaltend:**

Vergleichen des bestimmten Lenkrollradius mit einem spezifizierten Lenkrollradius; und Berechnen einer neuen Spur für das Rad, wenn der ermittelte Lenkrollradius nicht ungefähr mit dem spezifizierten Lenkrollradius übereinstimmt.

5

10

**5. Computergestützte Ausrichtungsvorrichtung zum Messen eines Lenkrollradius eines Rades, wobei die computergestützte Vorrichtung enthält:**

ein Ziel, das ein definiertes Muster aufweist und fest am Rad anbringbar ist;  
einen Sicht-Bildwandler zum Erfassen eines ersten Bildes des Ziels, wenn sich das Rad in einer ersten Position befindet, und zum Erfassen eines zweiten Bildes des Ziels, wenn sich das Rad in einer zweiten Position befindet; und  
einen Datenprozessor, der dafür programmiert, ist einen Lenkrollradius des Rades gemäß dem Verfahren nach irgendeinem der Ansprüche 1 bis 4 zu bestimmen.

15

20

25

**6. Vorrichtung nach Anspruch 5, wobei der Sicht-Bildwandler das erste Bild des Ziels durch optisches Abtasten des Ziels erfassst, wenn sich das Rad in der ersten Position befindet, und das zweite Bild des Ziels durch optisches Abtasten des Ziels erfassst, wenn sich das Rad in der zweiten Position befindet.**

30

**7. Vorrichtung nach Anspruch 5, wobei der Datenprozessor dafür programmiert ist, basierend auf dem ersten Bild des Ziels Werte zu erzeugen und zu speichern, die die erste Position des Rades darstellen, und basierend auf dem zweiten Bild des Ziels Werte zu erzeugen und zu speichern, die die zweite Position des Rades darstellen.**

35

40

**8. Vorrichtung nach Anspruch 5, wobei der Datenprozessor dafür programmiert, ist den ermittelten Lenkrollradius mit einem spezifizierten Lenkrollradius zu vergleichen und eine Warnung zu erzeugen, wenn der ermittelte Lenkrollradius nicht ungefähr dem spezifizierten Lenkrollradius entspricht.**

45

**9. Vorrichtung nach Anspruch 5, wobei der Datenprozessor dafür programmiert ist, den ermittelten Lenkrollradius mit einem spezifizierten Lenkrollradius zu vergleichen und eine neue Spur für das Rad zu berechnen, wenn der ermittelte Lenkrollradius nicht ungefähr dem spezifizierten Lenkrollradius entspricht.**

50

55

**10. Computerlesbares Medium, das eine oder mehrere Sequenzen von Anweisungen enthält, die dann,**

wenn sie von einem Prozessor ausgeführt werden, den Prozessor veranlassen, das Verfahren nach einem der Ansprüche 1 bis 4 auszuführen.

**Revendications**

**1. Procédé de mesure du rayon de pivotement du chemin de roulement d'une roue, comprenant les stades de :**

détermination d'un axe directeur, d'une ligne de centre et d'un plan de base d'une roue en utilisant un dispositif d'alignement assisté par ordinateur,  
dans lequel le plan de base est déterminé sur la base d'un axe de roulement déterminé et d'un rayon de roulement de la roue en faisant rouler la roue entre une première et une deuxième positions,  
de détermination d'une intersection entre l'axe directeur et le plan de base de la roue,  
de détermination d'une intersection entre la ligne de centre et le plan de base de la roue, et de détermination d'une distance entre les intersections, la distance comprenant le rayon de pivotement du chemin de roulement de la roue,  
dans lequel le dispositif d'alignement assisté par ordinateur comprend un dispositif de vision par machine en trois dimensions assisté par ordinateur, comportant des dispositifs de balayage optique et des cibles pouvant être balayés optiquement,  
et le procédé comprend aussi :

l'adjonction d'une cible pouvant être balayée optiquement et ayant une configuration définie à la roue ;  
le balayage optique de la cible quand la roue est dans la première position et la création et la mémorisation de valeurs représentant la première position ; et  
le balayage optique de la cible lorsque la roue est dans la deuxième position et la création et la mémorisation de valeurs représentant la deuxième position ;  
la détermination de l'angle, dont la roue a roulé entre la première et la deuxième positions ;  
le passage de la roue entre la première et la deuxième positions et la détermination de l'axe directeur de la roue sur la base des valeurs de position mémorisées ; et  
comportant, en outre, la détermination d'une épaisseur et d'un plan primaire de la roue et la détermination de la ligne de centre sur la base de l'épaisseur et du plan primaire.

2. Procédé suivant la revendication 1, dans lequel l'intersection entre l'axe directeur et le plan de base, l'intersection entre la ligne de centre et le plan de base et la distance entre les intersections sont déterminées en utilisant un dispositif d'alignement assisté par ordinateur.
3. Procédé suivant la revendication 1, comprenant, en outre :
- la comparaison du rayon de pivotement du chemin de roulement à un rayon de pivotement du chemin de roulement précisé ; et
- la production d'un avertissement, si le rayon de pivotement du chemin de roulement qui a été déterminé n'est pas à peu près égal au rayon de pivotement du chemin de roulement qui a été précisé.
4. Procédé suivant la revendication 1, comprenant, en outre :
- la comparaison du rayon de pivotement du chemin de roulement qui a été déterminé à un rayon de pivotement du chemin de roulement qui a été précisé ; et
- le calcul d'un nouveau pincement pour la roue, si le rayon de pivotement du chemin de roulement qui a été déterminé n'est pas à peu près égal au rayon de pivotement du chemin de roulement qui a été précisé.
5. Dispositif d'alignement assisté par ordinateur pour mesurer un rayon de pivotement du chemin de roulement d'une roue, dans lequel le dispositif assisté par ordinateur comprend :
- une cible ayant une configuration définie et pouvant être adjointe de manière fixe à la roue ;
- un imageur de vision pour détecter une première image de la cible lorsque la roue est dans une première position et pour détecter une deuxième image de la cible lorsque la roue est dans une deuxième position ;
- un processeur de données programmé pour déterminer un rayon de pivotement du chemin de roulement de la roue selon le procédé suivant l'une quelconque des revendications 1 à 4.
6. Dispositif suivant la revendication 5, dans lequel l'imageur de vision détecte la première image de la cible en balayant optiquement la cible, lorsque la roue est dans la première position, et détecte la deuxième image de la cible en balayant optiquement la cible, lorsque la roue est dans la deuxième position.
7. Dispositif suivant la revendication 5, dans lequel le processeur de données est programmé pour créer et mémoriser des valeurs représentant la première position de la roue sur la base de la première image de la cible et pour créer et mémoriser des valeurs représentant la deuxième position de la roue sur la base de la deuxième image de la cible.
8. Dispositif suivant la revendication 5, dans lequel le processeur de données est programmé pour comparer le rayon de pivotement du chemin de roulement qui a été déterminé à un rayon de pivotement du chemin de roulement qui a été précisé et pour produire un avertissement si le rayon de pivotement du chemin de roulement qui a été déterminé n'est pas à peu près égal au rayon de pivotement du chemin de roulement qui a été précisé.
9. Dispositif suivant la revendication 5, dans lequel le processeur de données est programmé pour comparer le rayon de pivotement du chemin de roulement qui a été déterminé à un rayon de pivotement du chemin de roulement qui a été précisé et pour calculer un nouveau pincement de la roue si le rayon de pivotement du chemin de roulement qui a été déterminé n'est pas à peu près égal au rayon de pivotement du chemin de roulement qui a été précisé.
10. Support pouvant être lu par ordinateur et effectuant une ou plusieurs séquences d'instruction, qui, lorsqu'elles sont exécutées par un processeur, font que le processeur effectue le procédé suivant l'une des revendications 1 à 4.

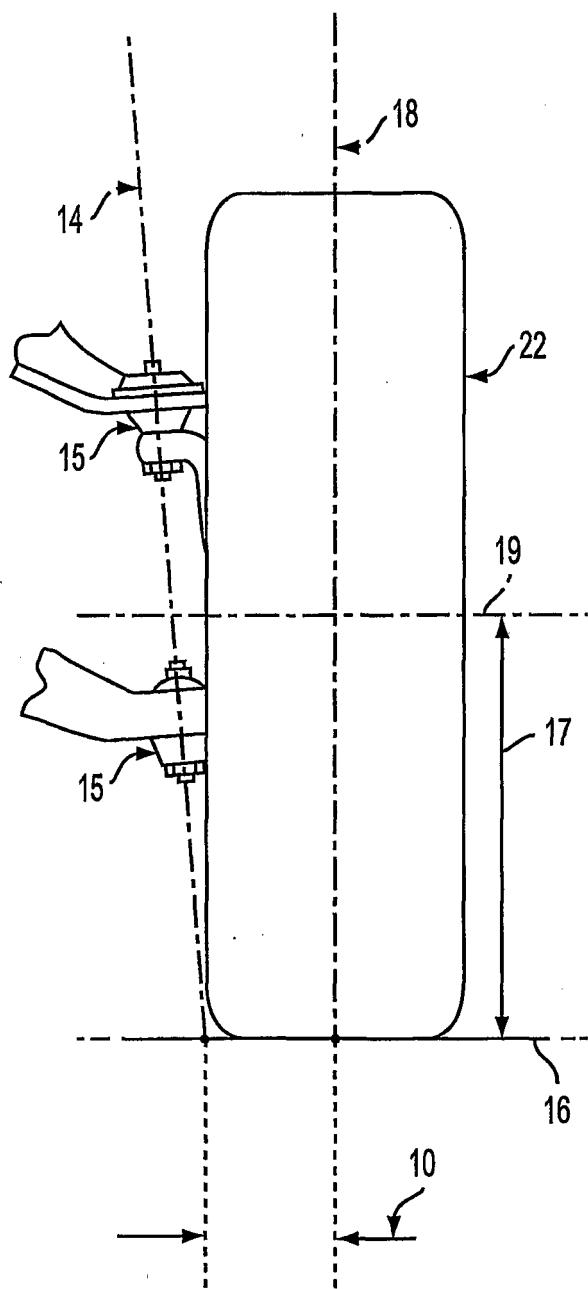


FIG. 1

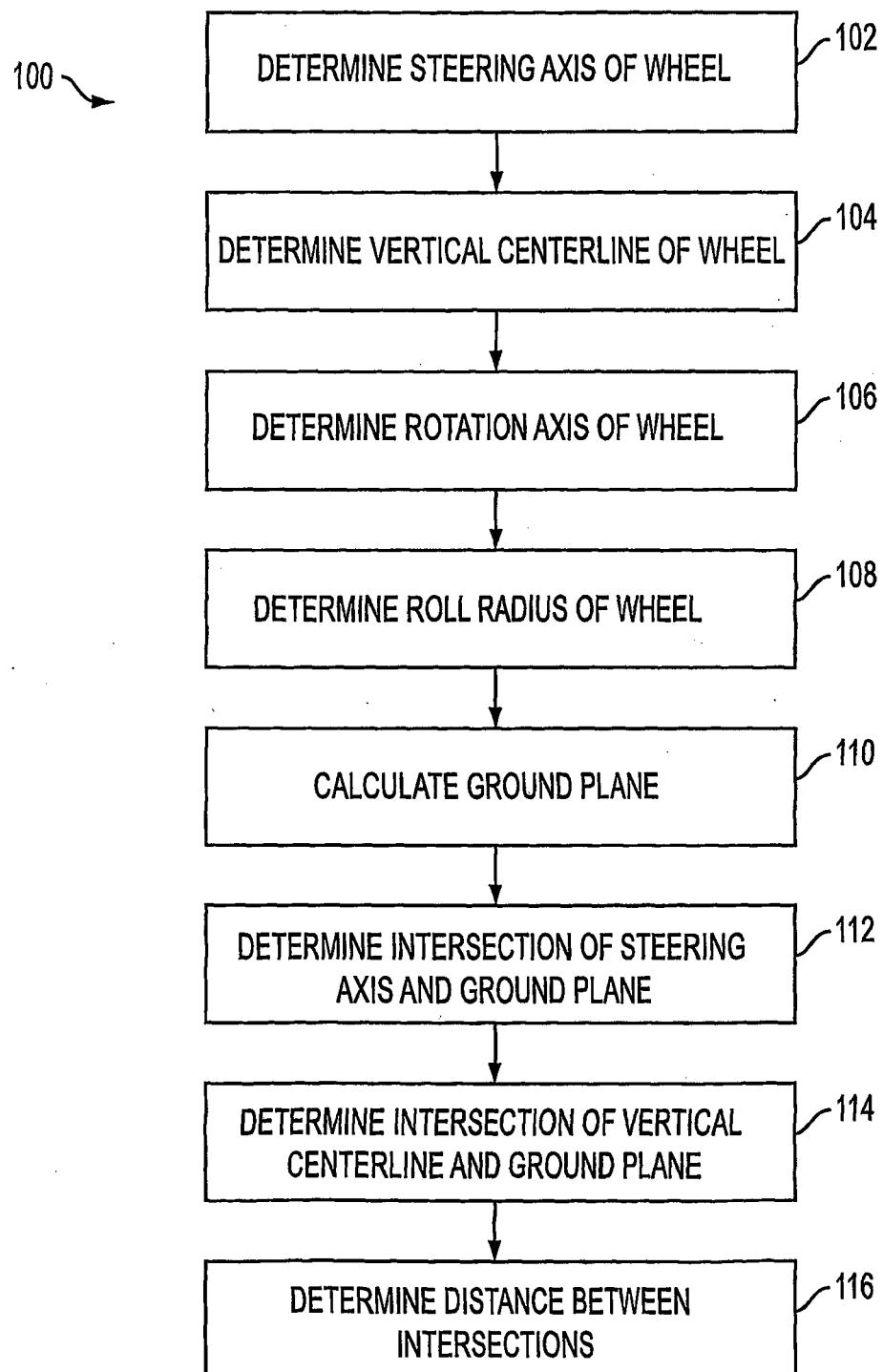


FIG. 2

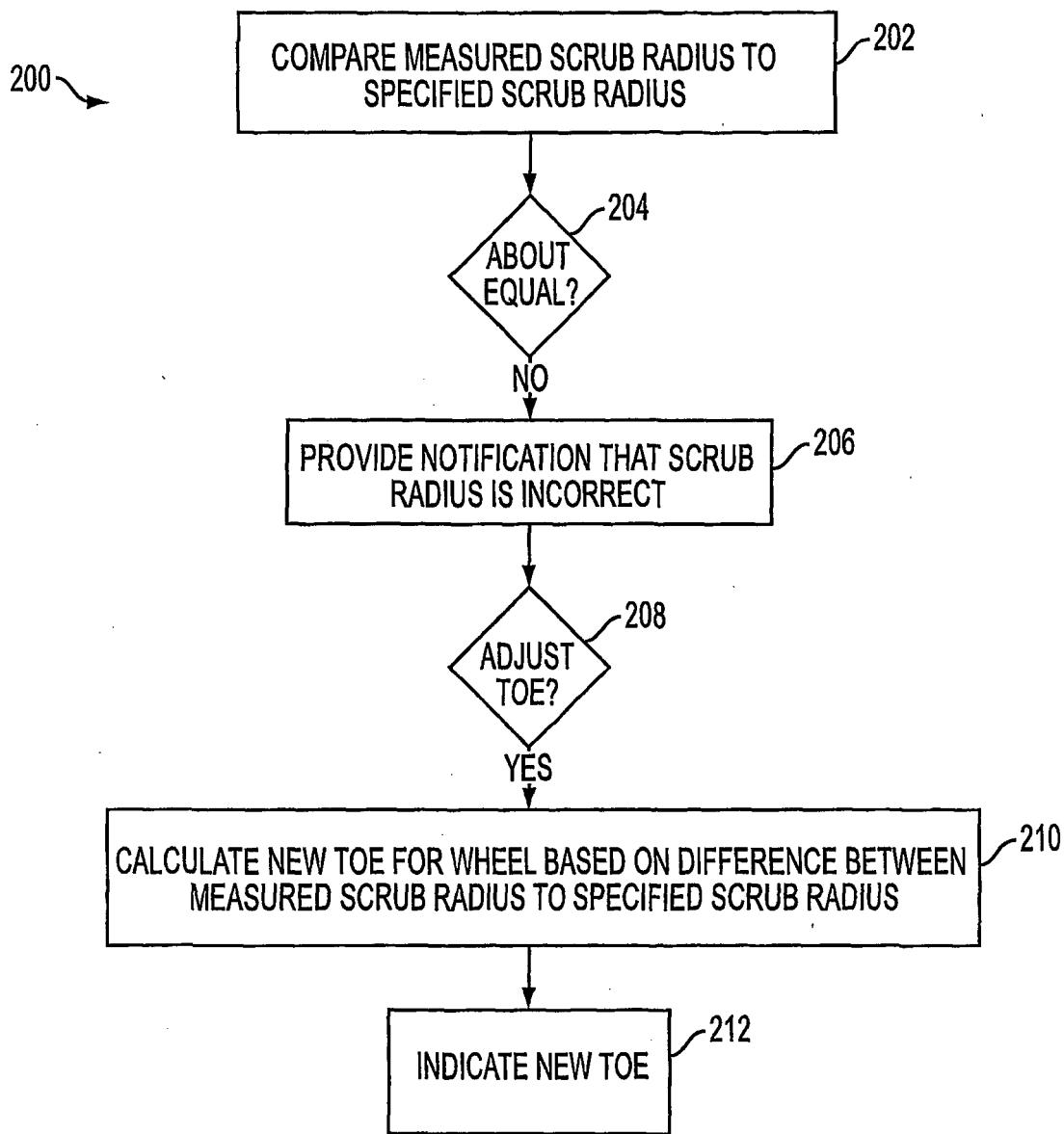


FIG. 3

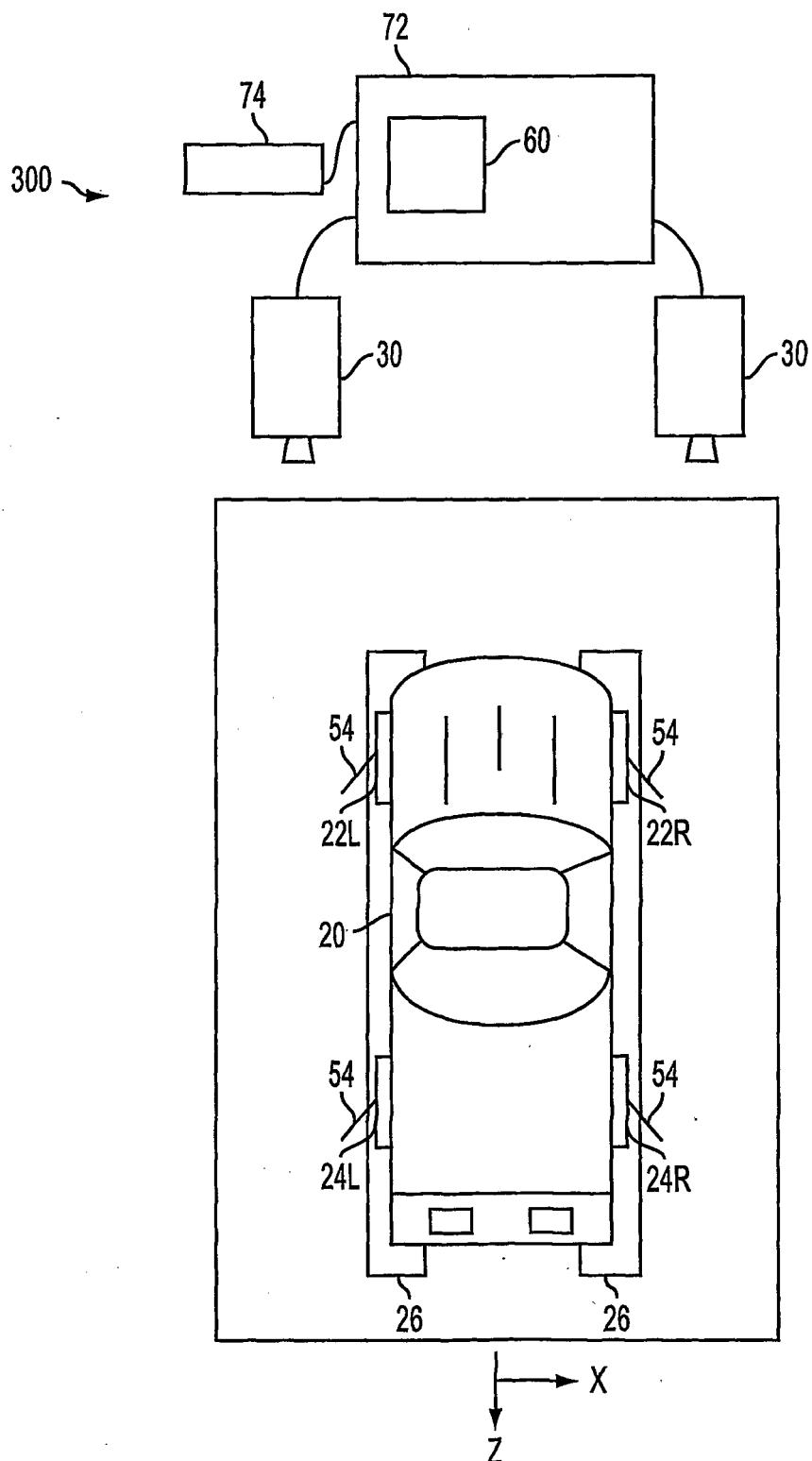
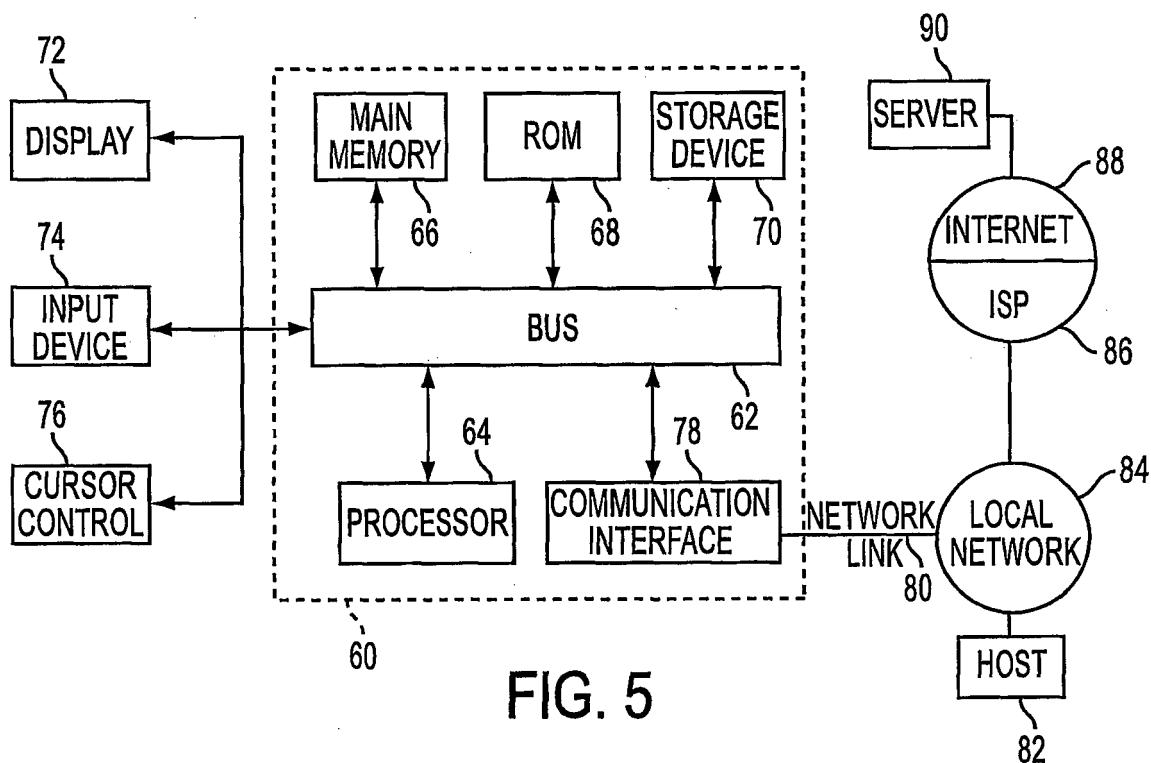


FIG. 4



**REFERENCES CITED IN THE DESCRIPTION**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- US 5724743 A [0003]
- US 5535522 A [0003]
- US 5291660 A [0004]
- US 5969246 A [0005]
- US 4106208 A [0006]
- US 4034479 A [0006]
- US 3782831 A [0007]
- US 3892042 A [0007]
- US 4095902 A [0007]
- US 4126943 A [0007]
- US 4138825 A [0007]
- US 4143970 A [0007]
- US 4302104 A [0007]
- US 4319838 A [0007]
- WO 0123834 A [0030]